FERTILIZER STUDIES WITH WHEAT IN THE PEACE RIVER REGION

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FERTILIZER STUDIES WITH WHEAT IN THE PEACE RIVER REGION

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ABSTRACT

Fertilizer experiments were conducted at 11 locations in the Peace River region representing the grey-wooded, degraded black and black soils. The crop used was wheat. The fertilizers used made it possible to compare the effect of applying the four major plant nutrients either singly or in combination.

With but one exception all the soils studied responded to applications of phosphate though the increases obtained were not always significant. One soil series showed a response to nitrogen. Phosphatic fertilizers generally promoted stronger root development, better tillering, fuller stands and hastened maturity by 3 to 5 days. Response to phosphate was generally associated with degraded black and black soils having a low pH value, and with grey-wooded soils having a low pH value, low organic matter content or both. The greatest yield increases were obtained on the degraded black and black soils.

Total analyses of these soils showed that they compare favourably with similar soils occurring elsewhere in the province. Even where the total phosphorus content of these soils was high they were found to be responsive to application of phosphate. With but a few exceptions these soils gave a low test for "available phosphates." The grey-wooded soils without exception gave a low test for "available nitrates."

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INTRODUCTION

The soils of the Peace River region are variable in their zonal characteristics. Grey-wooded soils constitute a large percentage of the total arable land, the acreage being estimated at 13 million acres (20). The acreage of arable black and degraded black soils is estimated at three and a half million acres. In the Alberta and British Columbia sections of the Peace River region the present acreage under cultivation is approximately one and a half million acres. It is, therefore, evident that future agricultural expansion in this region will be located primarily on grey-wooded soils. Because of their extent and the fertility problems associated with them it is important that these soils be studied closely.

In spite of its northern location the Peace River region enjoys a climate favourable to agriculture. Most of the region lies within north latitudes 55 to 58 which is indicative of its northern position. However, the mean annual temperature at Beaverlodge is 35.9°F., this being a 32-year average. This compares favourably with the Lacombe mean annual temperature of 36.3°F. in a 39-year average. At Beaverlodge the annual precipitation during the same 32 years has averaged 17.4 inches.

However, the distribution of precipitation is not always favourable since it is frequently heavy in the autumn months rather than in June and July when it would be most beneficial. These points should be kept in mind when considering fertilizer results.

Contrary to results obtained in west-central Alberta, Peace River soils to date have not responded to applications of sulphur-bearing fertilizers. This may be explained in part at least by the sulphate content of these soils as listed in Table 19 of the appendix.

This thesis is concerned with soil fertility in the Peace River region. The locations involved include black, degraded black and grey-wooded soils. The work being reported upon is intended to determine the fertilizer needs of the soils in various parts of the Peace River area.

REVIEW OF LITERATURE

Effect of Organic Matter

The amount of nitrogen in a soil varies widely depending upon the organic matter content. Shutt (23) concluded that grain growing as at present practised with its necessary summerfallow is destructive of the soil's organic matter with a corresponding loss of nitrogen. Newton *et al.* (12) found that the losses of nitrogen were not as great as those previously reported by Shutt at several locations in the prairie provinces but the trends were the same. They report that the losses of organic matter and nitrogen are greatest during the first few years after the land is broken.

Nitrogen is not the only nutrient the supply of which is affected by the level of soil organic matter. The phosphorus content of soils may also be affected by the amount of organic matter in the soil. Brown (1) found the average losses of total phosphorus from the top six inches of cultivated soils of the prairie provinces to be 105 pounds for black, 143 for dark brown, 144 for brown and 101 pounds per acre for grey soils. Below the six-inch depth the results are less accurate since the gains or losses are of an extremely low order. Pierre (16) states that the organic phosphorus in the surface layers of many soils constitutes at least one-third and in some cases such as prairie soils, as much as two-thirds of the total phosphorus. The amount decreases upon cropping as shown by Schollenberger. Cultivated soils were found to have lost about the same amounts of organic as of inorganic phosphorus. Pierre further states that Pearson in Iowa found that cropping had on the average reduced the inorganic phosphorus content of soils by 55 p.p.m., but the organic phosphorus by 83 p.p.m. These data indicate that organic phosphates are valuable from the standpoint of crop production. Odynsky (15) working with Alberta soils found that the organic phosphorus content of the surface horizons was about equal to the inorganic phosphorus content.

It would appear that where organic matter has been depleted by a period of cropping the phosphorus content is reduced or depleted along with the nitrogen content of the soil but the loss is not directly proportional to the loss of organic matter.

The rate and extent of phosphorus fixation has a bearing

on the response of crops to the application of phosphatic fertilizers. Maas and Bentley (10) report that high fixation in the podsolic Loon River soil is attributed to its low organic matter content. Swenson *et al.* (26) found that humus and lignin were effective in replacing phosphate from the basic iron phosphates.

Effect of Soil Reaction

While many factors are involved in phosphorus fixation the most important is perhaps soil reaction.

The literature contains many references to the relationships between soil pH and the utilization of phosphatic fertilizers by crops.

The acidity or alkalinity of soils may determine the availability of some plant nutrients. Pierre (17) states that in general acid clay soils, low in organic matter, give greater responses to phosphorus fertilizers than other soils of the same region. Maas and Bentley (10) found in the case of the black zone soils of Saskatchewan that the greatest amount of phosphorus fixation occurred in the most acid soils. Heslep (6) reports, after surveying the nutrient status of a large number of California soils, that phosphorus deficiency occurred in approximately 90 per cent of the soils having a pH below 6. Jones (8) reports that soil pH had a greater influence than any other single factor on the availability of phosphate in rock phosphate used as a fertilizer. Wursten (27) states that the so-called phosphorus fixation in calcareous soils is not as significant as it is in acid soils. He found when 100 pounds

per acre of a water soluble phosphate was added to a calcareous soil that its availability was reduced within 24 hours to 22-25 pounds per acre, after which a relatively constant level of availability was maintained.

Ensminger (3) found that certain soil conditions may affect the response obtained from phosphates. The more insoluble phosphates he says are usually better sources of phosphorus for acid soils than for alkaline soils. He further states that ammonium phosphates give relatively better response when applied to soils containing considerable calcium than when applied to light sandy soils low in calcium. Ensminger suggests that the lack of sulphur may be another reason for the low response obtained from ammonium phosphates.

<u>Availability of Phosphates</u>

A variety of investigations show the complexity of phosphorus relationships and behavior. Doughty (2) working with black, transitional and grey-wooded soils in Alberta reports that the soils investigated are in general high in water soluble or available phosphorus but that many of these soils responded to phosphatic fertilizers. He found that superphosphate alone, or lime and superphosphate increased the soluble phosphorus.

Odynsky (15) working with various Alberta soil profiles states that easily soluble phosphorus was found to be present in much larger quantities in the B_1, B_2, and C horizons of the brown zone profile than in the A_1 horizon. In the black zone profiles it was present in small to medium amounts in the A and

B_1 horizons and increased to form a large percentage of the total phosphorus in the B_2 or lime horizon. The grey zone profiles had a medium proportion of easily soluble phosphorus in their A_0 , A_1 and A_2, a small amount in the upper B_1 and then decidedly large amounts in the lower B_1, upper B_2 and lower B_2 horizons. He further states that organic phosphorus occurred in large amounts in the surface horizons, but below these the quantities of organic phosphorus diminished to very small amounts in the B_2 and C horizons.

Jacob et al. (7) working with potatoes found that on a silt loam the uptake of applied fertilizer was greater in low phosphorus soils than in phosphorus rich soils.

Effect of Soil Management

Sound soil management practices can do much to prevent losses of certain plant nutrients. Pierre (17) states that in many instances the extent of phosphorus deficiency is determined not by the soil type but by the treatment the soils have received since they were brought under cultivation. He reports that the work of Whitson and Stoddart showed that soils in Wisconsin which had been cropped to grain for 50 years had lost about one-third of the total phosphorus of the ploughed layer. Pierre further states that the cereal grains contain about 75 per cent of their total phosphorus content in the seed. When the seed leaves the field and farm about 75 percent of the phosphorus taken up by the plant is lost to the soil. Even where rotations including grasses and legumes were followed Pierre states that there was some loss of phosphorus by erosion in addition to that removed by the crop.

Large amounts of phosphorus are lost from the soil as the result of wind and water erosion according to Pierre. Phosphorus is found chiefly in the finer soil particles and these are the ones commonly carried away by wind and water.

Results with Fertilizers on Canadian Prairies

Field trials with commercial fertilizers on the numerous soil types encountered are necessary to forecast the plant nutrient needs of any specific area. Mitchell (11) states that the best fertilizer on the basis of trials conducted in Saskatchewan was 11-48-0 ammonium phosphate. Triple superphosphate gave smaller increases in yield at the same rates of P_2O_5. On the average the greatest increases in yield were obtained from the highest rates of application. He suggests, however, that low rates are considered the safest and best in a relatively dry region because of the fear that higher rates would produce a growth too luxuriant for the limited moisture supply to sustain. Mitchell recommends 11-48-0 at 20 to 40 pounds per acre.

Mitchell also found that the heavy soils showed the greatest response to phosphates, especially from the use of 11-48-0. On lighter soils the 11-48-0 showed a more favourable response in comparison to the 0-43-0 than on heavy or medium soils. This may be an indication of a nitrogen deficiency in the lighter soils, he says. Mitchell also observed that the heavier soils always appear to be well supplied with nitrates.

Fertilizer trials conducted at the Lacombe Experimental Station in Alberta (19) in a three-year rotation of summerfallow-wheat-wheat reveal that in a thirteen-year average 11-48-0

applied at 50 pounds per acre increased the yield of wheat after fallow by 8.9 bushels per acre. There was a residual effect on the second crop of wheat to the extent of 4.0 bushels per acre. It is, therefore, concluded that an application of 50 pounds per acre of 11-48-0 is profitable on the black soils of central Alberta where straight grain farming is practised.

At the University Farm, Edmonton, Alberta (28) on black soil ammonium phosphate (11-48-0) increased the yield of wheat by 4.7 bushels per acre in an eight-year average. Triple super-phosphate increased the yield of wheat by 4.5 bushels per acre for the same period.

At the Melfort Station in north-eastern Saskatchewan (21), 11-48-0 applied at 63 pounds per acre to wheat on summerfallow increased yields by nine bushels per acre in a nine-year average. In addition, the fertilized plots matured almost four days earlier than the untreated plots. The Station reports that on stubble the difference between the fertilized and untreated plots was not so great, however, the fertilized plots showed a greater net profit than the unfertilized plots.

Experimental work conducted with nitrogenous, potassic and phosphatic fertilizers on a long-term basis and reported by the Dominion Experimental Station located at Scott, Saskatchewan (22) has shown the phosphate fertilizers to be the only type which lead to increased wheat yields. This was found to hold true for oats and barley as well. In a six-year average over the period 1942 to 1947, 11-48-0 applied at 15 pounds per acre increased the yield of wheat by 4.4 bushels, while the 40-pound rate increased the yield by 6.9 bushels per acre. The Scott

Station recommends the light rate for use by farmers in that area.

Spinks and Barber (24), studying fertilizer uptake using radioactive phosphorus, report that greenhouse experiments indicate that: (a) There is no appreciable uptake of soil phosphorus until the plant is two weeks old; (b) The rate of uptake of fertilizer phosphorus is greatest between two and six weeks; (c) The rate of uptake of soil phosphorus increases for each succeeding two-week period; (d) The plant takes up fertilizer more rapidly than soil phosphorus for the first four weeks of growth. After four weeks the plant takes up soil phosphorus much more rapidly.

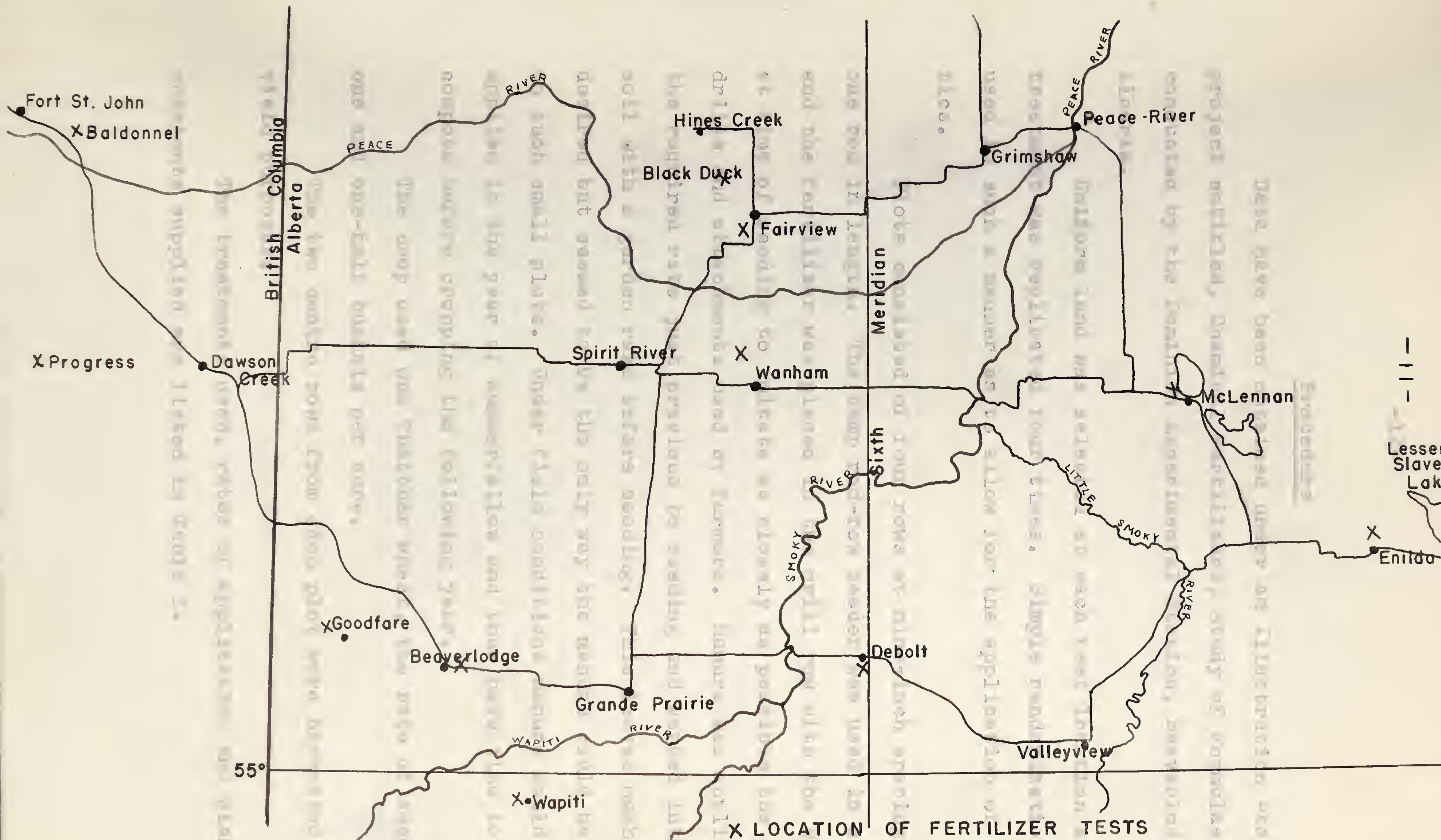
Their results suggest that the fertilizer phosphorus is drawn upon heavily in the early spring before the soil warms up and before the soil phosphorus becomes available. As the season advances the plants draw more heavily on soil phosphorus.

PURPOSE AND OUTLINE OF INVESTIGATION

The purpose of this investigation was to study the response of wheat to various plant nutrients supplied by commercial fertilizers, in an attempt to determine the fertilizer needs of various soil types found in the Peace River region. Plant nutrient elements were applied singly and in combination. Barnyard manure was included as a further treatment.

This report is concerned with 11 points in the Peace River region over the period 1947 to 1950 inclusive. Tests were located at the following points and are indicated on the map in figure 1;

Beaverlodge, Alberta
Baldonnel, B. C.
Black Duck, Alberta
Debolt, Alberta
Enilda, Alberta
Fairview, Alberta
Goodfare, Alberta
McLennan, Alberta
Progress, B. C.
Wanham, Alberta
Wapiti, Alberta



X LOCATION OF FERTILIZER TESTS

FIG. I. -- MAP OF THE PEACE RIVER REGION

X LOCATION OF FERTILIZER TESTS

FIG I -- MAP OF THE PEACE RIVER REGION

Procedure

Data have been obtained under an Illustration Station project entitled, Chemical Fertilizers, Study of Formulae, and conducted by the Dominion Experimental Station, Beaverlodge, Alberta.

Uniform land was selected at each test location and each treatment was replicated four times. Simple randomization was used in such a manner as to allow for the application of statistics.

Plots consisted of four rows at nine-inch spacings and one rod in length. The Kemp rod-row seeder was used in seeding and the fertilizer was placed in the drill row with the wheat at time of seeding to imitate as closely as possible the grain drills and attachments used by farmers. Manure was applied at the required rate just previous to seeding and worked into the soil with a garden rake before seeding. This leaves much to be desired but seemed to be the only way the manure could be applied on such small plots. Under field conditions manure would be applied in the year of summerfallow and thus have time to decompose before cropping the following year.

The crop used was Thatcher wheat, the rate of seeding one and one-half bushels per acre.

The two centre rows from each plot were harvested for yield purposes.

The treatments used, rates of application and plant nutrients supplied are listed in Table 1.

TABLE 1. TREATMENTS, RATES OF APPLICATION AND PLANT NUTRIENTS SUPPLIED

Treatment	Rate in pounds per acre	Plant nutrients supplied in pounds per acre			
		N	P_2O_5	K_2O	S
Check (no treatment)		-	-	-	-
Manure	15 tons	-	-	-	-
Ammonium nitrate	50 lbs.	16	-	-	-
Sulphur	20	-	-	-	20
Ammonium sulphate	80	16	-	-	20
Triple superphosphate	45	-	20	-	-
Amm. phos. (11-48-0)	45				
plus ammonium nitrate	36	16	20	-	-
Amm. phos. (16-20-0)	100				
plus sulphur	6	16	20	-	20
Amm. phos. (16-20-0)	100				
plus pot. sulphate	40	16	20	20	20

These applications allow for exact comparisons of plant nutrients on the basis of equal amounts of nitrogen, phosphorus, potassium or sulphur in the various treatments.

In most instances seedings were made on summerfallow but this practice was departed from in a few cases. In both seasons of testing wheat was seeded on newly broken land at Wanham. At Enilda all tests were seeded on stubble. In 1948 the tests at Goodfare, Progress and Wapiti were made on spring ploughed stubble and in 1949 the test at Baldonnel was seeded on spring ploughed stubble.

Soil Sampling

Soil samples were taken at all locations to represent surface soil and subsoil. Composite samples were obtained by mixing 10 separate samples taken throughout the plot areas at depths of

0-6 and 6-12 inches, respectively. These samples were held for purposes of chemical analyses.

Classification of Soils

All of the areas concerned have not been soil surveyed. Odynsky and Newton (13) classify the soil at McLennan as belonging to the Nampa series and that of Wanham as Davis. Odynsky (14) further suggests that some of the other soils concerned would be classified as follows:

Debolt	- Donnelly series
Black Duck	- " "
Goodfare	- " "
Wapiti	- " "
Enilda	- Enilda "
Fairview	- Belloy "
Beaverlodge	- Not determined

The Fairview soil while classified as Belloy is a deep phase of this series. It should be pointed out, that though the soil of any given location is classed in a certain series, that soil may vary somewhat from the description given. In general, however, it will conform insofar as the major characteristics are concerned. The soils of the Peace River region are extremely variable, hence variations from the type description may be greater in this area.

Farstad (4) suggests that the plot soils at the two locations in the British Columbia Peace River Block might be classified as follows:

Baldonnel	- Belloy series
Progress	- Progress series

Description of Soil Series (13) (14) (4)

Soils Developed on Lacustrine Deposited Material

Nampa Series: (Grey-wooded heavy loam to clay loam)

Nampa soils are poorly drained and are found in level and depressional areas. Their profile is quite similar to that of Donnelly soils except that the B horizon tends to be more compact and usually not as brown in colour. The brown colouring is evident in the upper part of the B horizon and merges gradually into the grey to dark grey colours characteristic of the parent material. It is a solodized profile in which the colour of the A horizons resembles that of other grey-wooded soils. This profile has very few to no stones. The cultivated top soil is usually greyish brown to light brownish-grey in colour.

Progress Series: (Grey-wooded loam)

Progress soils are not unlike the Donnelly soils in some features. They are developed on a very dark coloured heavy material, heavier and much darker than that of the Donnelly soils. While developed on lacustrine deposits they have an overlay of alluvial or aeolian origin. The Progress soils occupy areas of low relief and their internal drainage is rather slow. The B horizon consists of very firm clay having a well developed coarse columnar structure. The lower B consists of very firm clay which is extremely plastic when wet and has a well developed coarse blocky structure.

FIG. 2. Profile of Nampa Series.

Soils Developed on Alluvial and Aeolian Deposited Material

Davis Series: (Grey-wooded loam to silt loam)

These are well drained soils with a humpy, gently rolling to rolling topography. The knolls are low but often steep-sided. The native cover is a woodland vegetation consisting of aspen poplar, spruce, shrubs and coarse grasses. Sedges, and sometimes mosses are found in many of the poorly drained depressional areas associated with this series.

While Davis soils are classified as grey-wooded their profiles are usually much browner in colour than those of other grey-wooded soils. Often the darkest part of the solum is the lower part of the B horizon lying immediately above the lime horizon. In addition, thin strata that are reddish brown in colour sometimes occur at varying intervals in the B horizon. However, Davis soil profiles are quite variable. There is little uniformity as regards the depth to the different strata or as

regards the thickness of the respective strata. A solum that is predominantly silty is characteristic of these soils.

Variable Sandy to Silty Shore Line Material Overlying Till or Stratified Till Deposits

Belloy Series: (Degraded black to black sandy loam to silt loam)

The native cover is a fairly open woodland or parkland vegetation. The depth to the underlying heavier textured deposits is quite variable. These are degraded black to black soils in which the upper part of the profile is brown to black in colour, while the lower part is yellowish brown in colour and often platy. There is usually a gravelly or stony lens at the contact with the underlying heavier textured and often darker coloured material.

Soils Developed on Stratified Till or Modified Lacustrine Material

Donnelly Series: (Grey-wooded heavy loam to clay loam)

Donnelly soils are imperfectly or somewhat poorly drained soils. They have a grey, solodized profile in which the A_1 is either thin or absent, a grey A_2 horizon seldom exceeding a thickness of about four inches and a grey to greyish-brown nuciform AB or B_1 horizon. The remainder of the solum consists of a dark yellowish-brown to dark greyish-brown clay that is fairly compact, nuciform to small blocky, and in which small stones are of common occurrence. The lower part of the B horizon is often much darker coloured than is the upper part and this colour change may be quite abrupt. Accumulations of lime and salts are found at depths of 24 to 36 inches. The parent material is variable in colour

and may be predominantly brown or predominantly grey depending on the thickness and distribution of the yellowish-brown and dark grey strata. A few small stones are usually present in all horizons. On cultivation the surface soil is brownish grey in colour and tends to bake and crust on exposure.

FIG. 3. Profile of Donnelly Series.

Soils Developed on Glacial Till

Beaverlodge Profile: (Black solodized to slightly podsolic heavy loam to heavy silt loam)

This soil has not been named as to series but in many respects the dominant profiles in the vicinity of the plots resemble the Valleyview series which is a strongly solonetzic profile developed on a fairly well cemented, salty till which is underlain not too deeply by undisturbed bedrock. This profile is peculiar in that it is one of a small percentage of black profiles developed on glacial till. The Beaverlodge profile is not as strongly solonetzic as the Kavanagh series. It has more of an A_1 and A_2 and its B is not as tough nor as highly coated with black organic staining.

The parent till has had considerable sorting and there has possibly been some surface deposition. There is a medium depth of A_1, about six to eight inches with a relatively shallow A_2. The area in the vicinity of the plots is well drained. There is evidence of some podsolization superimposed on the original solodization.

FIG. 4. Beaverlodge Soil Profile

Relatively Immature Soils Developed on Recent Flood Plain Deposits

Enilda Series: (Black, weakly structured clay loam to clay)

This profile is fairly heavy textured but it is poorly drained as indicated by heavy iron staining. Horizon development is weak but there is an accumulation of organic matter (sedge peat) in the surface. The process of soil development has not gone far enough to give these soils distinctive horizon features.

Horse tail (Equisetum arvense) is a common weed on these soils.

FIG. 5. Profile of Enilda Series

MATERIALS AND METHODS

Before analysis all soil samples were ground by means of a Braun pulverizer. Acidity in terms of pH was determined by the Beckman pH meter. Nitrogen was determined by the Kjeldahl Gunning-Hibbard method, modified by the addition of selenium as a catalyst (18). Sodium carbonate fusion and subsequent determination colorimetrically by the Truog Colorimetric method was used to determine the phosphorus content of these soils. Calcium was precipitated as oxalate and titrated with potassium permanganate (9). Magnesium was precipitated as magnesium ammonium phosphate and determined according to the method of Handy (5). Available nitrate, phosphate, potash, calcium and magnesium were determined by the Spurway Quick Test method (25).

RESULTS

Soil Analysis

The data for chemical analyses performed are presented in Tables 2 and 3.

For the most part these soils are slightly acid in reaction. At Black Duck, Debolt, Enilda, Goodfare, Wanham and Wapiti, however, the surface soil is near the neutral point. These data substantiate the findings of Odynsky and Newton (13) in that the reactions of the soils in this area are of the same order as those of similar soils in other parts of Alberta.

The black soil at Beaverlodge has a low pH, 5.4 in the surface six inches. However, this may be due to its solonetzic tendency. The Wanham soil, which is of the Davis series, has a pH of 6.9 in the surface foot and 7.5 in the second foot. This series was developed on a parent material of high lime content. This is evident from the high lime content for the Wanham soil as shown in Table 2.

The nitrogen content of the soils at the 11 test locations compares favourably with the averages for grey-wooded and black soils in the other parts of the province. The Peace River soils, if anything, have a higher than average nitrogen content in the surface foot. For instance, the percentage nitrogen content in the surface six inches of grey-wooded soil at Debolt is 0.117 compared with an average of 0.091 per cent (13)

in the surface foot for grey-wooded soils in other parts of Alberta. On the other hand, black soil at Fairview contained 0.491 per cent nitrogen in the surface ten inches as compared to 0.407 per cent for the average black soils in other parts of Alberta.

The soil at Wanham falls below the average for the province in nitrogen content with 0.071 per cent in the surface foot.

The phosphorus content of soils is dependent upon the soils' parent material. Odynsky and Newton (13) state that analyses of the parent material of the area indicate that while they cannot be considered deficient in phosphorus their natural supply tends to be low. The phosphorus content of the plot soils appears upon examination, however, to compare very favourably with similar soils in other parts of Alberta.

For the most part these soils are well supplied with calcium, particularly in the lower horizons. The use of deep-rooted legumes necessary for soil improvement, at least on the grey-wooded soils, precludes the need for liming in that these plants will bring the lime to the surface.

The magnesium content of these soils appears to be adequate for plant growth and compares favourably with that of similar soils of good fertility found in other regions. The greatest concentration in almost every case is found in the lower horizons.

It is appreciated that in order that plant nutrients may be immediately useful to growing plants there must be an adequate supply of these elements in an easily soluble form which can be taken up by the plant in the soil solution. Availability tests

were, therefore, made.

In evaluating the data in Table 3, it should be borne in mind that field soils should probably contain 20 p.p.m. of nitrates, 2.5 to 5 p.p.m. of phosphorus, and 5 to 10 p.p.m. of potassium for good growth (25). It should also be noted that the nitrate content can change considerably throughout the season depending on moisture, temperature, tilth and growing crops. It follows, however, that a soil testing low in the three main nutrients will probably remain low if a crop is grown on it, and give below average yields.

Three of the soils in question, namely Baldonnel, Beaverlodge and Fairview, appear to be well supplied with nitrates. These represent the black soils. The soils at the remaining eight locations are low in available nitrates, with the exception of Black Duck and Enilda where the soils contain 14 and 10 p.p.m. respectively in the surface six inches. As would be expected the greatest concentration of nitrates is found in the surface six inches.

In available phosphorus, the Black Duck soil alone comes up to the standard of available phosphorus being used. Other experimental plot soils are low in available phosphorus.

With the exception of Beaverlodge, Fairview, Goodfare and Progress these soils conform to the standard being used with respect to available potassium. The soil at Progress appears to be extremely low in available potassium, while the soils at Beaverlodge, Fairview and Goodfare appear to be on the border line.

Available calcium appears to be in good supply in all soils but in the case of available magnesium a low test, 1 p.p.m. or less, indicates a deficiency if accompanied by a sickly, chlorotic appearance of the plants. The readings made range from 1 to 2 p.p.m. While these readings appear low, they were not associated with a chlorotic condition in the growth of wheat at any of the 11 test locations. This was an exacting test and the readings were difficult to make. It is assumed that the available magnesium in these soils is sufficient for good plant growth.

TABLE 2.--CHEMICAL COMPOSITION OF FERTILIZER EXPERIMENTAL PLOT SOILS

Location	Depth in inches	pH	Total analysis in percent			
			Nitrogen	Phosphorus	Calcium	Magnesium
Baldonnel	0- 6	6.1	0.344	0.110	0.78	0.43
"	6-16	6.1	0.046	0.108	0.46	0.43
Beaverlodge	0- 6	5.4	0.352	0.095	0.36	0.51
"	6-16	6.1	0.139	0.059	0.30	0.83
Black Duck	0- 6	6.8	0.120	0.075	0.32	0.47
"	6-18	7.5	0.057	0.049	0.18	0.74
Debolt	0- 6	6.8	0.117	0.056	0.32	0.32
"	6-16	5.5	0.055	0.041	0.46	0.81
Enilda	0- 8	6.5	0.348	0.078	1.04	0.58
"	8-16	7.3	0.076	0.059	1.02	0.48
Fairview	0-10	5.7	0.491	0.135	0.60	0.47
"	10-18	5.7	0.115	0.067	0.24	0.48
Goodfare	0- 6	6.8	0.172	0.062	0.34	0.32
"	6-16	5.2	0.082	0.044	0.54	0.66
McLennan	0- 6	5.2	0.098	0.086	0.42	0.37
"	6-16	4.8	0.068	0.047	0.32	0.63
Progress	0- 6	6.4	0.177	0.082	0.34	0.38
"	6-16	6.7	0.057	0.058	0.40	0.68
Wanham	0-12	6.9	0.071	0.055	0.34	0.48
"	12-24	7.5	0.079	0.055	3.12	0.76
Wapiti	0- 6	6.8	0.145	0.058	0.44	0.38
"	6-16	6.8	0.066	0.043	0.22	0.48

TABLE 3.--AVAILABLE PLANT NUTRIENTS IN FERTILIZER EXPERIMENTAL PLOT SOILS
(Spurway System of Testing)

Location	Depth in inches	Plant nutrients in parts per million				
		NO_3	P	Ca	K	Mg
Baldonnel	0- 6	18	0.75	130	10	1
"	6-16	1	0.75	100	tr.	1
Beaverlodge	0- 6	25	0.50	80	4	1
"	6-16	1	0.50	40	3	1
Black Duck	0- 6	14	2.50	100	3	0
"	6-18	1	tr.	100	12	1
Debolt	0- 6	5	0.75	120	3	0
"	6-16	1	tr.	100	12	1.5
Enilda	0- 8	10	1.00	140	20	2
"	8-16	5	0.75	150	18	1
Fairview	0-10	25	0.50	100	6	2
"	10-18	1	tr.	80	7	1
Goodfare	0- 6	4	1.00	130	3	1
"	6-16	1	tr.	80	4	1
McLennan	0- 6	1	1.00	100	12	1
"	6-16	1	tr.	80	18	1
Progress	0- 6	5	0.75	80	1	1
"	6-16	1	1.00	100	tr.	1.5
Wanham	0-12	2	2.00	60	2	1
"	12-24	1	1.00	200	20	1
Wapiti	0- 6	5	0.75	100	7	2
"	6-16	1	0.75	100	3	1

Crop Response

In order to understand and explain the response obtained with the different fertilizer treatments on the various soil series a resume of the seasons and history of the soil cropping is presented at this point. Precipitation data are available for several of the test locations and are presented in Table 4.

The soils under study have all been under cultivation from 10 to 20 years with the exception of Wanham where the test was located on land broken out of native sod in 1947. While some of these soils have been alternately cropped to grasses or legumes, generally speaking it can be said that they have been grain cropped.

Frosts accounted for yield reductions at most test locations in 1948 and again in 1950 though damage in 1948 was light. The four inches of snow which fell over the Peace River region in August, 1950 followed by from two to 12 degrees of frost broke down the crop and reduced grades and yields markedly. The most extensive damage occurred at Beaverlodge, Black Duck, Enilda, Goodfare, McLennan, Progress, Wanham and Wapiti. Yields were not taken at Wanham. Some frost damage also occurred in 1949 but damage was not extensive in the plot areas and yields were not markedly affected. Black Duck was the exception. This test was seeded late and was severely frosted. Yields were not taken.

Yield data by test locations are presented in Tables 6 to 16. Table 5 is included to show the average increases obtained over the untreated check with different fertilizer treatments.

For purposes of clarity, crop response as measured by summer growth and grain yields is discussed under soil series groups.

Beaverlodge Test (No Series Name)

In the four seasons of testing, summer notes make no mention of any response in growth or vigour resulting from applications of nitrogen or of sulphur singly. These plots showed no advantage over the untreated check plots. The manured plots were some better but not markedly superior to the check plot. In all plots to which phosphorus was applied, either singly or in combination with nitrogen, nitrogen and sulphur, or nitrogen, sulphur and potash, the growth was luxuriant and dense. Stooling was much better in these plots and the plants generally appeared to make faster growth. There was no appreciable difference between these four treatments.

Usually by mid-June the growth on plots to which phosphate had been applied was approximately double that on any other plot.

TABLE 4.--PRECIPITATION DATA 1947-1950

Location	Year	Precipitation for growing period in inches				
		April	May	June	July	Total
Baldonnel	1947	1.06	0.94	1.13	1.26	4.39
"	1948	1.99	1.01	1.01	3.83	7.84
"	1949	0.96	0.94	3.10	1.81	6.81
"	1950	2.10	2.16	3.25	2.69	10.20
Beaverlodge	1947	1.18	1.49	1.27	5.57	9.51
"	1948	2.28	0.84	0.83	3.88	7.83
"	1949	0.82	1.74	2.15	1.84	6.55
"	1950	0.96	2.20	0.55	2.42	6.13
Debolt	1947		no records			
"	1948	3.07	1.46	1.00	4.46	9.99
"	1949	0.85	1.15	0.63	3.28	5.91
"	1950	1.18	1.65	0.75	2.25	5.83
Fairview	1947	0.39	0.50	1.83	3.51	6.23
"	1948	1.84	0.12	2.31	1.18	5.45
"	1949	0.38	1.00	1.81	1.74	4.93
"	1950	1.04	1.52	2.07	2.93	7.56
Goodfare	1947		no records		4.42	
"	1948	3.44	0.65	0.83	3.87	8.79
"	1949	0.79	1.38	1.00	1.67	4.84
"	1950	2.37	1.96	0.45	3.27	8.05
McLennan	1947		no records			
"	1948	1.65	1.09	0.31	2.63	5.68
"	1949	0.26	1.31	2.33	3.89	7.79
"	1950		no records			
Progress	1947	0.00	1.39	1.37	1.86	4.62
"	1948	0.85	0.74	0.41	-	-
"	1949	-	no records		-	-
"	1950	1.40	2.44	0.96	2.25	7.05

FIG. 6. Left Check, Right 11-48-0 plus Ammonium nitrate, Beaverlodge, 1949.

FIG. 7. Left Ammonium Nitrate, Right Check,
Beaverlodge, 1949.

Beaverlodge results for the four years reported show some definite trends.

As shown in Table 7 the average increase obtained from applications of barnyard manure was 3.1 bushels per acre. The increases have varied with individual years, ranging from -0.2 to 6.1 bushels. In some seasons strawy manure was used. This together with the method of application, may account for the poor average response from manure in the tests reported here.

Long-term trials at Beaverlodge have proved the value of manure when applied in the year of summerfallow.

The results indicate that on the Beaverlodge soil nitrogen alone in the form of ammonium nitrate or ammonium sulphate is not beneficial, nor is sulphur. Phosphate alone gave almost as good results as nitrogen and phosphate. It appears, however, that some nitrogen with the phosphorus is required for optimum results. On the other hand, it could be that the phosphate is more readily available in the ammonium phosphate form than it is in the calcium phosphate form. Sulphur or potash when added to the formula did not increase the yields over those obtained with the nigrogen-phosphorus combination.

FIG. 8. Left Triple Superphosphate, Right Sulphur, Beaverlodge, 1949.

Belloy Series

At Fairview the test has been located on land which was broken out of brome sod in 1946. This soil is a deep phase of the Belloy series. Moisture has been in good supply and yields have been above average for the district generally.

Observations made during the growing season in each year of testing have suggested the value of phosphate fertilizers or nitrogen-phosphorus combinations. In no instance has nitrogen alone promoted extra vigour or growthiness of stands. Stooling and consequent thicker stands have always been associated with those plots receiving phosphorus, whether alone or in combination with other plant nutrients. Barnyard manure has also promoted extra growth.

The yield data substantiate observations made during the growing season. Phosphorus alone was as beneficial as the nitrogen-phosphorus or other combinations containing phosphorus. This soil was high in organic matter and it is suggested that in older field soils where the organic matter has been depleted the nitrogen-phosphorus treatment might show up to greater advantage. The addition of sulphur or potash does not appear to be warranted on this soil.

At Baldonnel, on a shallow phase of this series, field observations made during the growing period suggest that manure is valuable as a soil amendment. Also the fertilizers containing phosphorus have promoted extra growth and vigour in all years of testing. Generally speaking, the complete formula has appeared the most promising of the four treatments that include

phosphorus. Nitrogen alone has not produced growth or vigour comparable to that obtained in the phosphate treated plots nor have the nitrogen plots shown any superiority over the untreated check plots. Sulphur applied singly has not promoted growth superior to that of the check plots.

The yield data substantiate the field observations. They suggest that the application of phosphorus can be expected to increase yields but that additions of potash may serve to further increase yields of wheat. Nitrogen alone did not promote an increase in yield over the check nor did sulphur.

Davis Series

Tests on Davis soils were located on newly broken land in the Veterans' block of the Wanham project. This soil had been worked to considerable depth and was very dry at time of seeding in 1948 and 1949. Yields were surprisingly high considering the general lack of moisture in the area.

Observations made during the growing season suggested that nitrogen might be the limiting factor in crop production. This may further have been accentuated by the fact that much nitrogen was being utilized in the rotting of sod and debris. The tests were somewhat variable as indicated by the large value for minimum significant difference.

The yield data substantiate observations made during the growing season, namely that nitrogen was the limiting factor in crop growth on these soils. While no significant yield increases were obtained the trends favour those fertilizers which contain nitrogen.

Donnelly Series

Results vary somewhat on this series. Differences in moisture supply and extent of frost damage during the period of testing may account for some of the variations.

At Black Duck no marked differences were noted between treatments during the growing period. It did appear, however, that those plots to which phosphate was applied either singly or in combination were superior to the other plots in growth and vigour. Barnyard manure appeared to promote better growth on this soil.

The yield data agree generally with the observations made throughout the growing period.

There appeared to be no advantage in adding sulphur or potash to the treatments.

At Debolt notes taken during the growing period in each year of testing emphasized the value of phosphorus alone and in combination with nitrogen. These plots always appeared superior from the standpoint of growth and vigour. The plots receiving single applications of nitrogen or sulphur were not superior in any way to the untreated checks. Barnyard manure applications promoted extra growth and vigour in all cases.

By mid-June in each year the plots to which phosphorus, nitrogen-phosphorus, nitrogen-phosphorus-sulphur or nitrogen-phosphorus-sulphur-potash applications were made were taller and twice as growthy as the untreated check. This difference was marked and showed up in photographs taken. This difference was attributed to better root development and consequently better stooling in these plots.

The yield data follow the same trends established during the growing season. There was no suggestion that the further addition of sulphur or sulphur and potash was beneficial. As in the case of the Beaverlodge test the data suggest that a nitrogen-phosphorus fertilizer can be expected to give the best results.

FIG. 9. Left Nitrogen and Phosphorus,
Right Nitrogen Alone,
Debolt, 1949.

Moisture has generally been in better supply at Debolt than at the other test points located on the Donnelly soils. This will largely explain the more favourable results obtained with fertilizers at Debolt.

In the three years of testing at Goodfare no significant increases have been obtained with any of the commercial fertilizers applied. The general trends favour those fertilizers containing phosphorus alone or in combination with nitrogen. Dry seasons and early frosts did much to mask the beneficial effects of fertilizers. This is particularly true of the 1950 season.

The differences between treatments were not as marked at Wapiti as they were at Debolt as gauged by crop growth. The general trends, however, favoured phosphorus or phosphorus in combination with nitrogen, etc.

All fertilizers containing phosphorus gave definite yield increases but only three out of a possible 16 were significant. The results indicate, as in the case of Debolt, that some nitrogen with the phosphorus is required. The addition of sulphur or sulphur and potash does not appear to be warranted.

Enilda Series

In the years under test moisture has not been a limiting factor at Enilda and yields have been good. The low yield obtained in 1950 is the result of the heavy frost which occurred on August 17th. The crop was very immature and consequently was severely frosted.

The yield data suggest that a fertilizer containing nitrogen and phosphorus is the most beneficial. This is borne out by the comparison with triple superphosphate and with the complete fertilizer. Nitrogen alone does not appear to be beneficial nor does sulphur or potash appear to be required.

Nampa Series

The McLennan test was located on soil representative of this series.

In the four years of testing at this location notes taken over the growing season suggest that the wheat in the plots to which the four phosphate-bearing fertilizers were

applied emerged stronger, and developed better root systems as gauged by the more extensive stooling in these plots. Where flash rains occurred shortly after seeding the soil baked very hard. It was noted that in all instances the crop emerged through this crusted layer and made near full stands in the plots receiving an application of phosphate. The untreated check plots and the sulphur or nitrogen treated plots emerged slowly and made poor stands under such conditions. This condition is attributed to the stronger root development in the plots receiving applications of fertilizer containing phosphorus.

The value of barnyard manure is emphasized by the average yield increase of 5.7 bushels per acre. Significant increases were obtained in three of the four seasons of testing.

The yield data suggest that nitrogen or sulphur alone are not beneficial to crops grown on these soils. While phosphorus alone gave substantial increases it is evident that a nitrogen-phosphorus fertilizer is most beneficial. The further addition of sulphur or sulphur and potash does not appear to be beneficial.

Progress Series

At Progress exceptionally dry seasons were encountered and in 1947 particularly the soil baked following a flash rain immediately following seeding. Where barnyard manure or fertilizers containing phosphorus were applied germination was satisfactory and the plants were able to push up through the crusted soil. In the check plots and in the plots receiving nitrogen or sulphur alone the plants emerged slowly and stands were thin and

patchy. The fuller stands in the case of the phosphate treated plots were attributed to stronger root development.

The yield data suggest that phosphate can be depended upon to bring about yield increases. The addition of potash to the phosphorus or phosphorus-nitrogen fertilizers appears to be beneficial.

TABLE.5-AVERAGE CHECK YIELDS AND AVERAGE INCREASES OBTAINED OVER UNTREATED CHECKS IN BUSHELS PER ACRE (1947-1950)

Location	Average yield of check	Average increases obtained over untreated check in bushels per acre							
		Manure	Ammonium nitrate	Sulphur	Amm. sul-phate	Triple super-phos-phate	Am. phos. (11-48-0) plus amm. nitrate	Am. phos. (16-20-0) plus sulphur	Am. phos. (16-20-0) plus pot. sulphate
Baldonnel	25.7	5.4 (3)	0.1	0.6	0.1	5.8 (2)	6.5 (2)	6.6 (3)	10.1 (3)
Beaverlodge	16.3	3.1	-0.6	0.3	0.8	8.9 (3)	11.2 (4)	11.6 (4)	9.6 (4)
*Black Duck	14.1	6.4 (1)	0.3 (1)	0.5	-1.1	2.1 (1)	1.7 (1)	-0.1	3.0
Debolt	15.0	6.9 (4)	-0.5 (1) decr.	-0.2	0.1	5.0 (2)	7.2 (3)	6.4 (2)	7.3 (3)
Enilda	15.9	1.2	0.4	0.6	1.1	1.9	4.9 (2)	3.0 (2)	2.9 (2)
Fairview	30.8	5.2 (3)	0.6	1.7 (1)	1.0	7.5 (3)	7.6 (3)	6.2 (3)	6.4 (3)
*Goodfare	11.5	1.1	0.1	-0.9	-0.8	0.7	2.1	1.2	2.5
McLennan	8.8	5.7 (3)	-0.7	-0.5	-1.5	3.6 (2)	4.8 (2)	4.6 (4)	4.8 (2)
*Progress	4.0	2.8 (1)	0.3	-0.6	0.1	3.4 (2)	4.1 (2)	2.8 (1)	5.8 (3)
**Wanham	19.7	-	3.9	1.0	2.5	1.8	3.3	4.1	2.6
Wapiti	15.9	2.7 (1)	0.2	0.4	-2.8	3.2	3.7 (1)	3.5 (1)	4.4 (1)

*Three-year average.
**Two-year average.
NOTE: Figures in parenthesis indicate the number of years in which significant increases were obtained.

TABLE 6.--ROD-ROW FERTILIZER TRIALS WITH WHEAT, BALDONNEL, B. C. (1947-1950)

Treatment	Rate per acre in pounds	Plant nutrients supplied in pounds per acre				Yield in bushels per acre					
		N	P_2O_5	K_2O	S	1947	1948	1949	1950	4-year average	Average increase over untreated check
Check	-	-	-	-	-	20.7	25.8	39.5	16.9	25.7	-
Manure	15T	-	-	-	-	25.2	36.3	40.2	22.5	31.1	5.4 (3)
Amm. nitrate	50	16	-	-	-	17.6	29.8	39.5	16.3	25.8	0.1
Sulphur	20	-	-	-	20	19.8	26.7	42.8	16.0	26.3	0.6
Amm. sulphate	80	16	-	-	20	17.7	27.5	41.1	16.8	25.8	0.1
T. S. P.	45	-	20	-	-	24.7	35.8	42.6	23.0	31.5	5.8 (2)
A. P. (11-48-0) plus amm. nitrate	45 36	16	20	-	-	23.0	37.3	44.7	23.7	32.2	6.5 (2)
A. P. (16-20-0) plus sulphur	100 6	16	20	-	20	26.8	33.0	45.7	23.7	32.3	6.6 (3)
A. P. (16-20-0) plus pot. sulphate	100 40	16	20	20	20	29.0	42.6	45.2	26.4	35.8	10.1 (3)
M. S. D.						4.4	5.4	7.0	4.3		

NOTE: Figures in parenthesis in average increase column indicate the number of years in which significant increases were obtained.

TABLE 7.--ROD-ROW FERTILIZER TRIALS WITH WHEAT, BEAVERLODGE, ALBERTA (1947-1950)

Treatment	Rate per acre in pounds	Plant nutrients supplied in pounds per acre				Yield in bushels per acre					
		N	P_2O_5	K_2O	S	1947	1948	1949	1950	4-year average	Average increase over untreated check
Check	-	-	-	-	-	22.4	17.8	20.9	4.0	16.3	-
Manure	15T	-	-	-	-	24.8	21.9	27.0	3.8	19.4	3.1
Amm. nitrate	50	16	-	-	-	20.2	16.7	22.7	3.0	15.7	-0.6
Sulphur	20	-	-	-	20	22.9	19.2	19.9	4.5	16.6	0.3
Amm. sulphate	80	16	-	-	20	23.1	17.2	22.6	5.3	17.1	0.8
T. S. P.	45	-	20	-	-	30.6	34.2	27.0	9.0	25.2	8.9 (3)
A. P. (11-48-0) plus amm. nitrate	45 36	16	20	-	-	36.4	36.7	28.0	8.7	27.5	11.2 (4)
A. P. (16-20-0) plus sulphur	100 6	16	20	-	20	36.0	36.9	30.2	8.6	27.9	11.6 (4)
A. P. (16-20-0) plus pot. sulphate	100 40	16	20	20	20	31.2	36.6	28.2	7.5	25.9	9.6 (4)
M. S. D.						4.3	4.5	6.4	1.8		

NOTE: Figures in parenthesis in average increase column indicate the number of years in which significant increases were obtained.

TABLE 8.--ROD-ROW FERTILIZER TRIALS WITH WHEAT, BLACK DUCK, ALBERTA (1947-1950)

Treatment	Rate per acre in pounds	Plant nutrients supplied in pounds per acre				Yield in bushels per acre					
		N	P_2O_5	K_2O	S	1947	1948	1949	1950	3-year average	Average increase over untreated check
Check	-	-	-	-	-	16.5	21.2	-	4.5	14.1	-
Manure	15T	-	-	-	-	17.5	36,9	-	7.1	20.5	6.4 (1)
Amm. nitrate	50	16	-	-	-	15.8	19.7	-	7.7	14.4	0.3 (1)
Sulphur	20	-	-	-	20	15.9	24.0	-	4.0	14.6	0.5
Amm. sulphate	80	16	-	-	20	15.3	19.0	-	4.7	13.0	-1.1
T. S. P.	45	-	20	-	-	16.0	24.3	-	8.2	16.2	2.1 (1)
A. P. (11-48-0) plus amm. nitrate	45 36	16	20	-	-	19.7	20.6	-	7.2	15.8	1.7 (1)
A. P. (16-20-0) plus sulphur	100 6	16	20	-	20	19.1	16.3	-	6.7	14.0	-0.1
A. P. (16-20-0) plus pot. sulphate	100 40	16	20	20	20	20.1	24.6	-	6.5	17.1	3.0
M. S. D.						5.4	10.9		2.7		

NOTE: Figures in parenthesis in average increase column indicate the number of years in which significant increases were obtained.

TABLE 9.--ROD-ROW FERTILIZER TRIALS WITH WHEAT, DEBOLT, ALBERTA (1947-1950)

Treatment	Rate per acre in pounds	Plant nutrients supplied in pounds per acre				Yield in bushels per acre					
		N	P_2O_5	K_2O	S	1947	1948	1949	1950	4-year average	Average increase over untreated check
Check	-	-	-	-	-	16.6	19.4	9.9	14.2	15.0	-
Manure	15T	-	-	-	-	20.5	25.4	15.7	26.1	21.9	6.9 (4)
Amm. nitrate	50	16	-	-	-	11.8	19.2	12.6	14.4	14.5	-0.5 (1) decrease
Sulphur	20	-	-	-	20	16.4	18.1	11.8	12.8	14.8	-0.2
Amm. sulphate	80	16	-	-	20	15.5	18.6	10.1	16.1	15.1	0.1
T. S. P.	45	-	20	-	-	21.9	21.7	17.6	18.7	20.0	5.0 (2)
A. P. (11-48-0) plus amm. nitrate	45 36	16	20	-	-	23.5	23.1	19.3	23.0	22.2	7.2 (3)
A. P. (16-20-0) plus sulphur	100 6	16	20	-	20	23.8	22.8	20.8	18.0	21.4	6.4 (2)
A. P. (16-20-0) plus pot. sulphate	100 40	16	20	20	20	26.9	23.1	20.1	19.0	22.3	7.3 (3)
M. S. D.						3.8	4.3	3.6	4.6		

NOTE: Figures in parenthesis in average increase column indicate the number of years in which significant increases were obtained.

TABLE 10.--ROD-ROW FERTILIZER TRIALS WITH WHEAT, ENILDA, ALBERTA (1947-1950)

Treatment	Rate per acre in pounds	Plant nutrients supplied in pounds per acre				Yield in bushels per acre					
		N	P_2O_5	K_2O	S	1947	1948	1949	1950	4-year average	Average increase over untreated check
Check	-	-	-	-	-	19.6	15.4	22.2	6.5	15.9	-
Manure	15T	-	-	-	-	21.8	15.9	25.3	5.4	17.1	1.2
Amm. nitrate	50	16	-	-	-	21.5	14.8	22.9	5.8	16.3	0.4
Sulphur	20	-	-	-	20	22.5	16.0	22.1	5.4	16.5	0.6
Amm. sulphate	80	16	-	-	20	21.2	16.3	24.8	5.7	17.0	1.1
T. S. P.	45	-	20	-	-	23.5	16.7	24.3	6.5	17.8	1.9
A. P. (11-48-0) plus amm. nitrate	45 36	16	20	-	-	26.3	18.5	30.4	7.9	20.8	4.9 (2)
A. P. (16-20-0) plus sulphur	100 6	16	20	-	20	24.8	16.2	27.8	6.8	18.9	3.0 (2)
A. P. (16-20-0) plus pot. sulphate	100 40	16	20	20	20	24.5	16.6	28.9	5.1	18.8	2.9 (2)
M. S. D.						3.5	N.S.	4.6	2.1		

NOTE: Figures in parenthesis in average increase column indicate the number of years in which significant increases were obtained.

TABLE 11.--ROD-ROW FERTILIZER TRIALS WITH WHEAT, FAIRVIEW, ALBERTA (1947-1950)

Treatment	Rate per acre in pounds	Plant nutrients supplied in pounds per acre				Yield in bushels per acre					
		N	P_2O_5	K_2O	S	1947	1948	1949	1950	4-year average	Average increase over untreated check
Check	-	-	-	-	-	34.2	28.8	35.6	24.6	30.8	-
Manure	15T	-	-	-	-	44.0	31.6	38.5	29.8	36.0	5.2 (3)
Amm. nitrate	50	16	-	-	-	38.7	28.0	34.6	24.2	31.4	0.6
Sulphur	20	-	-	-	20	41.5	29.9	35.4	23.2	32.5	1.7 (1)
Amm. sulphate	80	16	-	-	20	39.9	26.3	35.4	25.4	31.8	1.0
T. S. P.	45	-	20	-	-	44.3	30.7	43.7	34.3	38.3	7.5 (3)
A. P. (11-48-0) plus amm. nitrate	45 36	16	20	-	-	44.5	29.1	45.9	34.1	38.4	7.6 (3)
A. P. (16-20-0) plus sulphur	100 6	16	20	-	20	44.3	30.6	41.9	31.3	37.0	6.2 (3)
A. P. (16-20-0) plus pot. sulphate	100 40	16	20	20	20	42.5	29.0	44.8	32.6	37.2	6.4 (3)
M. S. D.						6.1	2.8	4.4	3.0		

NOTE: Figures in parenthesis in average increase column indicate the number of years in which significant increases were obtained.

TABLE 12.--ROD-ROW FERTILIZER TRIALS WITH WHEAT, GOODFARE, ALBERTA (1948-1950)

Treatment	Rate per acre in pounds	Plant nutrients supplied in pounds per acre				Yield in bushels per acre				
		N	P_2O_5	K_2O	S	1948	1949	1950	3-year average	Average increase over untreated check
Check	-	-	-	-	-	10.1	22.0	2.3	11.5	-
Manure	15T	-	-	-	-	12.8	22.2	2.8	12.6	1.1
Amm. nitrate	50	16	-	-	-	11.7	21.4	1.6	11.6	0.1
Sulphur	20	-	-	-	20	9.4	20.2	2.2	10.6	-0.9
Amm. sulphate	80	16	-	-	20	9.7	21.0	1.5	10.7	-0.8
T. S. P.	45	-	20	-	-	13.2	21.6	1.8	12.2	0.7
A. P. (11-48-0) plus amm. nitrate	45 36	16	20	-	-	13.4	25.7	1.6	13.6	2.1
A. P. (16-20-0) plus sulphur	100 6	16	20	-	20	12.4	23.8	1.9	12.7	1.2
A. P. (16-20-0) plus pot. sulphate	100 40	16	20	20	20	13.4	26.3	2.3	14.0	2.5
M. S. D.						3.4	4.4	1.9		

NOTE: Figures in parenthesis in average increase column indicate the number of years in which significant increases were obtained.

TABLE 13.--ROD-ROW FERTILIZER TRIALS WITH WHEAT, McLENNAN, ALBERTA (1947-1950)

Treatment	Rate per acre in pounds	Plant nutrients supplied in pounds per acre				Yield in bushels per acre					
		N	P_2O_5	K_2O	S	1947	1948	1949	1950	4-year average	Average increase over untreated check
Check	-	-	-	-	-	12.0	2.8	14.4	5.9	8.8	-
Manure	15T	-	-	-	-	8.3	5.7	25.7	18.2	14.5	5.7 (3)
Amm. nitrate	50	16	-	-	-	9.3	2.1	15.4	5.5	8.1	-0.7
Sulphur	20	-	-	-	20	8.7	2.7	13.9	7.8	8.3	-0.5
Amm. sulphate	80	16	-	-	20	10.3	2.0	11.2	5.7	7.3	-1.5
T. S. P.	45	-	20	-	-	14.4	6.1	16.1	12.8	12.4	3.6 (2)
A. P. (11-48-0) plus amm. nitrate	45 36	16	20	-	-	17.0	4.2	18.3	14.7	13.6	4.8 (2)
A. P. (16-20-0) plus sulphur	100 6	16	20	-	20	17.6	4.5	19.7	11.9	13.4	4.6 (4)
A. P. (16-20-0) plus pot. sulphate	100 40	16	20	20	20	19.7	3.9	18.6	12.3	13.6	4.8 (2)
M. S. D.						4.5	1.6	4.9	4.1		

NOTE: Figures in parenthesis in average increase column indicate the number of years in which significant increases were obtained.

TABLE 14.--ROD-ROW FERTILIZER TRIALS WITH WHEAT, PROGRESS, B. C. (1947-1950)

Treatment	Rate per acre in pounds	Plant nutrients supplied in pounds per acre				Yield in bushels per acre					
		N	P_2O_5	K_2O	S	1947	1948	1949	1950	3-year average	Average increase over untreated check
Check	-	-	-	-	-	3.6	6.5	-	1.9	4.0	-
Manure	15T	-	-	-	-	8.5	9.0	-	2.9	6.8	2.8 (1)
Amm. nitrate	50	16	-	-	-	2.5	8.3	-	2.1	4.3	0.3
Sulphur	20	-	-	-	20	1.8	6.2	-	2.2	3.4	-0.6
Amm. sulphate	80	16	-	-	20	2.5	7.5	-	2.2	4.1	0.1
T. S. P.	45	-	20	-	-	10.2	8.2	-	3.7	7.4	3.4 (2)
A. P. (11-48-0) plus amm. nitrate	45 36	16	20	-	-	11.4	10.1	-	2.7	8.1	4.1 (2)
A. P. (16-20-0) plus sulphur	100 6	16	20	-	20	9.8	9.0	-	1.7	6.8	2.8 (1)
A. P. (16-20-0) plus pot. sulphate	100 40	16	20	20	20	13.4	12.5	-	3.6	9.8	5.8 (3)
M. S. D.						1.9	2.7		1.4		

NOTE: Figures in parenthesis in the average increase column indicate the number of years in which significant increases were obtained.

TABLE 15.--ROD-ROW FERTILIZER TRIALS WITH WHEAT, WANHAM, ALBERTA (1948-1949)

Treatment	Rate per acre in pounds	Plant nutrients supplied in pounds per acre				Yield in bushels per acre			
		N	P_2O_5	K_2O	S	1948	1949	2-year average	Average increase over untreated check
Check	-	-	-	-	-	19.6	19.7	19.7	-
Manure	15T	-	-	-	-	-	-	-	-
Amm. nitrate	50	16	-	-	-	22.4	24.7	23.6	3.9
Sulphur	20	-	-	-	20	22.9	18.4	20.7	1.0
Amm. sulphate	80	16	-	-	20	20.0	24.3	22.2	2.5
T. S. P.	45	-	20	-	-	23.0	20.0	21.5	1.8
A. P. (11-48-0) plus amm. nitrate	45 36	16	20	-	-	19.6	26.4	23.0	3.3
A. P. (16-20-0) plus sulphur	100 6	16	20	-	20	20.8	26.7	23.8	4.1
A. P. (16-20-0) plus pot. sulphate	100 40	16	20	20	20	19.2	25.3	22.3	2.6
M. S. D.						5.7	8.1		

NOTE: Figures in parenthesis in average increase column indicate the number of years in which significant increases were obtained.

TABLE 16.--ROD-ROW FERTILIZER TRIALS WITH WHEAT, WAPITI, ALBERTA (1947-1950)

Treatment	Rate per acre in pounds	Plant nutrients supplied in pounds per acre				Yield in bushels per acre					
		N	P_2O_5	K_2O	S	1947	1948	1949	1950	4-year average	Average increase over untreated check
Check	-	-	-	-	-	16.6	14.1	28.0	4.8	15.9	-
Manure	15T	-	-	-	-	19.4	20.3	27.7	7.0	18.6	2.7 (1)
Amm. nitrate	50	16	-	-	-	15.8	14.6	30.2	3.7	16.1	0.2
Sulphur	20	-	-	-	20	18.0	15.3	27.9	4.1	16.3	0.4
Amm. sulphate	80	16	-	-	20	15.5	12.1	21.6	3.2	13.1	-2.8
T. S. P.	45	-	20	-	-	20.1	18.1	32.3	6.0	19.1	3.2
A. P. (11-48-0) plus amm. nitrate	45 36	16	20	-	-	19.5	18.8	35.7	4.3	19.6	3.7 (1)
A. P. (16-20-0) plus sulphur	100 6	16	20	-	20	21.1	16.9	33.7	6.0	19.4	3.5 (1)
A. P. (16-20-0) plus pot. sulphate	100 40	16	20	20	20	23.4	17.5	35.0	5.3	20.3	4.4 (1)
M. S. D.						4.0	4.2	9.7	2.3		

NOTE: Figures in parenthesis in the average increase column indicate the number of years in which significant increases were obtained.

TABLE 17.--AVERAGE INCREASES FOR FERTILIZERS ON GREY-WOODED SOILS, 1947-1950

Fertilizer treatment	Rate in pounds per acre	No. of plots	Average increase in bushels per acre	Number of results	
				Significant	Not significant
Manure	15T	21	4.3	10	11
Ammonium nitrate	50	23	0.5	1 increase 1 decrease	21
Sulphur	20	23	-0.04	0	23
Ammonium sulphate	80	23	-0.5	0	23
Triple superphosphate	45	23	2.8	7	16
Ammonium phosphate (11-48-0) plus ammonium nitrate	45 36	23	3.8	9	14
Ammonium phosphate (16-20-0) plus sulphur	100 6	23	3.2	8	15
Ammonium phosphate (16-20-0) plus potassium sulphate	100 40	23	4.3	9	14

TABLE 18.--AVERAGE INCREASES FOR FERTILIZERS ON BLACK AND DEGRADED BLACK SOILS, 1947-1950

Fertilizer treatment	Rate in pounds per acre	No. of plots	Average increase in bushels per acre	Number of results	
				Significant	Not significant
Manure	15T	16	3.7	6	10
Ammonium nitrate	50	16	0.1	0	16
Sulphur	20	16	0.8	1	15
Ammonium sulphate	80	16	0.8	0	16
Triple superphosphate	45	16	6.0	8	8
Ammonium phosphate (11-48-0) plus ammonium nitrate	45 36	16	7.6	11	5
Ammonium phosphate (16-20-0) plus sulphur	100 6	16	6.9	12	4
Ammonium phosphate (16-20-0) plus potassium sulphate	100 40	16	7.3	12	4

DISCUSSION OF RESULTS

The average results reported for grey-wooded soils and for degraded black and black soils (Tables 17 and 18) indicate a response to phosphorus and nitrogen-phosphorus fertilizers on the summerfallow wheat crop in the Peace River region. The greatest yield increases were obtained on the degraded black and black soils.

Of the soil series under study the Davis series alone failed to respond to phosphorus applied singly. The response on these soils was obtained rather with nitrogen. It should be pointed out that this soil was low in total nitrogen (Table 2) and in available nitrates (Table 3). The pH of this soil was 6.9 in the surface foot and 7.5 in the second foot. This suggests that the phosphorus in the soil may be in more available form than that in some of the other soils of the region (10)(17)(6). The calcium content of this soil was high, 3.12 per cent in the second foot. This may further explain the lack of response to fertilizer phosphorus. Wursten (27) found that phosphorus fixation in calcareous soils was not as significant as it was in acid soils.

The two tests on the Davis series soils were located on newly broken virgin sod. The response to nitrogen may be attributed in part, therefore, to the heavy drain on nitrogen for decomposition of sod and buried debris.

In general the effects of phosphate with respect to earlier maturity, better tillering, fuller stands and better

weed competition as reported by Mitchell (11) were observed. The effects on maturity were variable, however, and in 1948 and 1950 particularly were masked by frost damage. Generally, however, it is conceded that phosphatic fertilizers hastened maturity by 3 to 5 days. The effect of phosphatic fertilizers upon tillering was marked, particularly when June moisture was adequate (Figures 6, 7, 8 and 9).

With but a few exceptions the average percentage increases obtained with phosphatic fertilizers are not as high as reported for the dark brown and black soils of Saskatchewan (11). Comparable increases were obtained at Beaverlodge (Table 7), Debolt (Table 9), Fairview (Table 11), McLennan (Table 13) and Progress (Table 14).

Experimental results suggest that a formula containing nitrogen and phosphorus can be expected to give better results than phosphorus alone. The test at Fairview conducted on a heavy phase of the Belloy series (degraded black to black sandy loam to silt loam) developed on till or stratified till deposits does not conform to this general pattern. This particular soil was high in organic matter and was exceptionally high in total nitrogen (Table 2). Also a satisfactory test for "available nitrates" was obtained for this soil (Table 3). The suggestion of Wyatt _et al._ (29) that nitrification would undoubtedly be less for the wooded (podsol-like) soils than for the black soils might explain the response at Fairview.

The greatest responses with phosphatic fertilizers were obtained on the most acid soils, i.e., Baldonnel, Beaverlodge,

Debolt, Fairview, McLennan and Progress and were associated with pH values of 6.4 or lower.

The soils in the Peace River region are generally spoken of as cold soils. This would seem to be justified in that all soils studied were heavy soils as suggested by the descriptions, heavy loam, clay loam, heavy silt loam, and clay, etc. As suggested by Spinks and Barber (24) response to phosphates on these soils may be due to the fact that phosphates are not readily available to the wheat plants for the first two weeks of growth. Fertilizer phosphorus is, therefore, drawn upon for root development. Once the plants have developed a strong root system they are in a better position to make full use of available soil phosphorus when it is released.

That phosphatic fertilizers promoted stronger root development was demonstrated at McLennan and at Progress on Nampa and Progress soil series. In seasons when flash rains occurred shortly after seeding the soil baked very hard making emergence of the seedling plants exceedingly difficult. It was noted, however, that in all instances the wheat plants emerged through the crusted layer and made almost full stands in the plots receiving applications of phosphorus fertilizers. The untreated check plots and the sulphur or nitrogen treated plots emerged slowly and made poor stands. This ability to emerge through the crusted layer was attributed to the stronger root development in the phosphate treated plots.

The application of 20 pounds per acre of sulphur did not result in increased yields of wheat nor did it result in

increased yields when applied in combination with nitrogen and phosphorus.

The addition of 20 pounds per acre of potash in the form of K_2O to make up a complete fertilizer appeared to increase the yield of wheat at Baldonnel and at Progress (Tables 5, 6 and 14). The increase over the nitrogen-phosphorus combination at Baldonnel was significant in one out of four seasons only, while at Progress one significant increase out of a possible three was obtained. It is suggested that these soils may be on the border-line of potash deficiency. This is supported by "available potash" tests (Table 3), however, other soils studied were equally low but did not respond to potash treatments.

The chemical analyses of the experimental plot soils (Table 2) suggest that these soils compare favourably with similar soils in other parts of Alberta with respect to their total nitrogen and phosphorus content. The Peace River soils, if anything, have a higher than average nitrogen content in the surface foot. The soils under study were all low in "available phosphate" (Table 3) and only three soils came up to the standard of available nitrates being used. These were the Baldonnel, Beaverlodge and Fairview plot soils representing the black and degraded black soils.

In comparison with most western Canada prairie soils the soils included in this study are comparatively new. For the most part Peace River soils have been under cultivation for only 15 to 30 years. It is quite conceivable that soils giving only light responses to phosphatic fertilizers now may respond in a more definite manner after they have been cropped for a

period of 40 to 50 years. This is to be expected if the soils are managed on a fallow-grain basis (17)(23).

In many respects the seasons for the period of this study were unfavourable to fertilizer usage in that drought together with early autumn frosts did much to obliterate their beneficial effect.

On the average barnyard manure increased yields of wheat by 4.3 bushels per acre for the grey-wooded soils and 3.7 bushels per acre for the black and degraded black soils. Greater increases than these have been obtained at Beaverlodge and on the Illustration Stations in the region where the manure was applied in the summerfallow year. In some instances manure seemed to dry out the soil in the tests reported upon, while in some trials late July and early August precipitation resulted in late growth with consequent frost damage in these plots. This resulted in lower average yield increases than the growth in the plots would suggest.

The experimental data suggest that on the grey-wooded soils an application of 11-48-0 at approximately 40 pounds per acre can be expected to increase yields by three to four bushels per acre in an average season. Under more favourable conditions yield increases of five to seven bushels per acre may be expected. On the degraded black and black soils yield increases up to 10 bushels per acre may be expected.

The results of this study indicate that increases of five bushels per acre of wheat might be expected annually on the wheat land of the Peace River region. On the basis of some

741,000 acres cropped to wheat in 1949 and based on Canadian Wheat Board Permit Declarations the application of 40 pounds per acre of ammonium phosphate (11-48-0) might be expected to increase wheat production in this region by some 3,705,000 bushels at a profit of approximately $2,593,500 (1950 prices). This does not take into account the increased profits to be derived from fertilizing the 400,000 acres of oats and 122,000 acres of barley grown.

SUMMARY

Results are given for fertilizer trials conducted on some of the main soil types found in the Peace River region. The fertilizers used make it possible to compare the effect of applying the four main plant nutrients either singly or in combination.

The data suggest that with few exceptions the grey-wooded, degraded black and black soils of this region respond to applications of phosphate. Generally speaking, best results are obtained where some nitrogen is included in the fertilizer, i.e., ammonium phosphate (11-48-0).

Total analyses of these soils indicate that they compare favourably with similar soils occurring elsewhere in the province. The grey-wooded soils generally are better supplied with total nitrogen than the average grey-wooded soils of the province. Even where the total phosphorus content of these soils was high they were found to be responsive to applications of phosphate.

Response to phosphate was generally associated with degraded black and black soils having a low pH value, and with grey-wooded soils having a low pH value, low organic matter content or both.

With but a few exceptions these soils gave low tests for "available phosphates."

The grey-wooded soils without exception gave low tests for "available nitrates."

Phosphatic fertilizers promoted stronger root development with consequent better tillering and fuller stands.

Phosphatic fertilizers hastened maturity by 3 to 5 days.

Barnyard manure generally increased yields. However, in dry seasons the manure appeared to dry out the soil, while in seasons of excessive autumn moisture the manure often delayed maturity, thus subjecting the crop to frost damage and reduced yields.

In seasons of average precipitation most soils in the Peace River region can be expected to give paying responses to the application of nitrogen-phosphorus fertilizers.

The soils under study do not respond to sulphur; this may be explained in part at least by the sulphate content of these soils.

There is an indication that potash may be required in combination with nitrogen and phosphorus at Baldonnel and at Progress.

With the possible exception of the Davis series the

soils under study do not respond to applications of nitrogen alone either in the form of ammonium nitrate or ammonium sulphate.

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APPENDIX

Data in connection with water soluble salts are presented in Table 19. These analyses were made in 1942 by the Soil Research Laboratory, Experimental Station, Swift Current, Saskatchewan.

They report that the apparent uniformity of magnesium concentrations is due to titrations of approximately 0.5 c.c., being reported as 0.005% and lower ones as a trace. Sodium was determined by differences in all cases.

TABLE 19.--PERCENT WATER SOLUBLE SALTS

Location	Depth in inches	Ca.	Mg.	Na.	CO_3	HCO_3	Cl.	SO_4	Total	Land treatment
Wapiti,	0- 6	.008	.005	-	-	.02	T	.017	.050	Native land
Alta.	6-12	.007	.005	-	-	.02	-	.015	.047	
"	12-24	.011	.005	.005	-	.05	T	.018	.089	
"	0- 6	.008	T	.005	-	.02	T	.015	.048	After one crop
"	6-12	.007	T	.011	-	.02	T	.028	.066	alfalfa
"	12-24	.011	.005	.005	-	.05	T	.016	.087	
"	0- 6	.008	.005	-	-	.01	T	.010	.033	After two crops
"	6-12	.006	T	.015	-	.05	-	.008	.079	alfalfa
"	12-24	.011	.005	-	-	.04	.002	.011	.079	
"	0- 6	.005	.005	-	-	.01	.003	.010	.033	After several crops
"	6-12	.006	.005	-	-	.01	.002	.007	.030	alfalfa
"	12-24	.008	.010	-	-	.03	T	.006	.054	
Goodfare,	0- 6	.010	.001	.001	-	.02	-	.016	.048	Native land
Alta.	6-12	.006	.001	.011	-	.04	T	.012	.070	
"	12-24	.006	T	.003	-	.01	.002	.013	.034	
"	0- 6	.007	.001	-	-	.01	-	.012	.030	Old land seeded to
"	6-12	.006	.001	-	-	.01	T	.011	.028	sweet clover in 1942
"	12-24	.005	.001	-	-	.01	-	.016	.032	
"	0- 6	.006	T	.002	-	.01	T	.012	.030	do
"	6-12	.007	T	.004	-	.01	T	.018	.039	
"	12-24	.005	T	.004	-	.01	T	.014	.033	

TABLE 19.--PERCENT WATER SOLUBLE SALTS (CONTINUED)

Location	Depth in inches	Ca.	Mg.	Na.	CO_3	HCO_3	Cl.	SO_4	Total	Land treatment
Progress,	0- 6	.005	.005	-	-	.01	-	.006	.026	Native sod
B. C.	6-12	.004	T	.002	-	.01	-	.006	.022	
"	12-24	.009	.005	-	-	.05	T	.005	.069	
"	0- 6	.004	T	.002	-	.01	T	.006	.022	Meadow land seeded
"	6-12	.003	.005	-	-	.01	T	.005	.023	in 1942. Broken
"	12-24	.010	.005	.004	-	.05	T	.021	.090	several years
"	0- 6	.003	.005	-	-	.02	-	.010	.038	Stubble land broken
"	6-12	.002	T	.008	-	.01	T	.015	.035	several years
"	12-24	.011	.005	.004	-	.05	T	.018	.083	
Beaverlodge	0- 6	.006	.005	-	-	.02	T	.017	.048	Composite of Exp.
Experimental	6-12	.003	.005	-	-	.01	T	.017	.035	Station soil at
Station	12-24	.003	T	.009	-	.01	T	.020	.042	Beaverlodge

TABLE 19.--PERCENT WATER SOLUBLE SALTS (CONTINUED)

Location	Depth in inches	Ca.	Mg.	Na.	CO_3	HCO_3	Cl.	SO_4	Total	Land treatment
Debolt,	0- 6	.008	T	-	-	.01	T	.013	.031	Native land
Alta.	6-12	.005	T	.005	-	.02	T	.014	.044	
"	12-24	.006	T	.025	-	.04	T	.037	.108	
"	0- 6	.004	T	.007	-	.01	T	.017	.038	Fallow
"	6-12	.004	T	.005	-	.01	T	.013	.032	
"	12-24	.007	.005	.006	-	.05	T	.014	.082	
"	0- 6	.004	T	.003	-	.01	T	.004	.026	Alfalfa seeded in
"	6-12	.003	T	.006	-	.01	-	.012	.031	1940
"	12-24	.002	.005	-	-	.01	T	.009	.026	
Baldonnel,	0- 6	.008	.005	-	-	.02	.002	.014	.039	Native land
B. C.	6-12	.004	.005	-	-	.07	.002	.011	.032	
"	12-24	.006	.005	.005	-	.01	.005	.010	.041	
"	0- 6	.008	.005	-	-	.02	.005	.010	.048	After about five
"	6-12	.007	.005	-	-	.01	T	.007	.029	cereal crops
"	12-24	.006	.005	-	-	.02	T	.007	.038	
"	0- 6	.006	-	-	-	.01	T	.011	.027	Old land broken
"	6-12	.006	.005	-	-	.01	-	.011	.032	about 1929
"	12-24	.005	T	.003	-	.01	-	.011	.029	